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Current Data on the Taxonomic Composition and Distribution of the Trawl Macrozoobenthos in Russian Waters of the Sea of Japan

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Abstract—A complex bottom trawl survey (430 stations) was conducted over all of the shelf and continental slope (within a depth range of 10–750 m) in the Russian waters of the Sea of Japan from April 1 to July 8, 2015. A total of 211 taxa of invertebrates were recorded from trawl catches. The most widely represented of them were starfish (36), shrimps (32), gastropods (27), bivalves (23), brachyuran and anomuran crabs (11), polychaetes (11), coral polyps (10), and sponges (10). The total recorded biomass of macrozoobenthos in benthic biotopes of the northern Sea of Japan reached 1572 500 t (136 600 t in Peter the Great Bay, 341 500 t in the Southern Primorye area, 686 000 t in the northern Primorye area, and 408 400 t in the Western Sakhalin subzone), which is higher than the mean long-term level. The total stock of commercial invertebrates was estimated at 630 000 t. Its largest portion (265 200 t, or 42.1%) was concentrated in the northern Primorye area (western Tatar Strait). The mean specific biomass of the trawl macrozoobenthos constituted 13.5 ± 1.1 g/m^2 (including 6.3 ± 0.5 g/m^2 of commercial benthic species). The most abundant groups were brittle stars (372 200 t), brachyuran crabs (231 600 t), anomuran crabs (48 700 t), shrimps (226 900 t), sponges (182 900 t), sea lilies (167 500 t), starfish (77 200 t), sea urchins (59 000 t), and bivalves (49 500 t). The vertical distribution of the total benthos and its commercial portion was characterized by maxima in the upper shelf (10–50 m) and within a depth range of 300–400 m. In the northwestern Sea of Japan, 18 biocenotic complexes of trawl macrozoobenthos were identified. The largest areas were occupied by the group of the sedentary seston-feeding sea lily *Heliometra glacialis* (biomass 5.5 g/m^2, depth range of 104–692 m, 131 stations), the group of the polyphagous snow crab *Chionoecetes opilio* (4.4 g/m^2, 27–552 m, 71 stations), the group of the mobile seston-feeding basket star *Gorgonocephalus eucnemis* (6.6 g/m^2, 58–372 m, 40 stations), and the group of the polyphagous pale yellow sea urchin *Strongylocentrotus pallidus* (4.7 g/m^2, 17–351 m, 40 stations).

Keywords: trawl survey, biomass, macrozoobenthos, crabs, shrimp, Peter the Great Bay, Primorye subzone, Western Sakhalin subzone

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INTRODUCTION

The northern Sea of Japan is a region of long-term commercial fishing for both fish and invertebrates [9, 12, 17], in particular, red king crab, harvesting of which in Peter the Great Bay began in 1874 [7]. Since the 1980s, with the launch of biocenological studies by the Pacific Research Institute of Fisheries and Oceanography (TINRO), the object-oriented fisheries research, focused on common commercial fish species, has been reorganized into a complex study of the composition and structure of pelagic and benthic fish communities [3, 4, 10, 11, 39, etc.].

Benthos, as a forage base for commercial animals and a component of ecosystems, has until recently been studied mainly by the method of surveys using bottom grab samplers[1] [23–25]. However, if a grab sampler makes it possible to collect representative materials on the composition of endobenthos of soft sediments, collecting the inhabitants of hard sediments, as well as megabenthos (sponges, buccinids, corals, starfishes, etc.), with tools of this class does not provide reliable data. In this case, surveys with divers are organized to study the epibenthos in shallow waters, [35, 36]; for surveying the zone of shelf and continental slope, a bottom trawl net is the most suitable tool. Until recently, data from trawl surveys in waters of the Sea of Japan were used only for object-oriented studies of commercial invertebrates: sculptured shrimp [22], Japanese cucumaria [2], buccinid gastropods [30], brachyuran and anomuran crabs [17, 33], as well as deep-sea shrimp [6, 18, 19]. Publications with the information on the composition of trawl benthos in certain regions of Russian waters of the Sea of Japan, such as Peter the Great Bay [5] and the Tatar Strait [28], have appeared only in recent years. Generalized estimates of the composition, quantitative dis-

[1] In addition, benthic communities of soft sediments are sometimes studied using bottom dredge samplers [25].

Table 1. The surveyed areas of bathymetric ranges used in calculations, km^2

Area	Depth range, m							Total
	10–50	50–100	100–200	200–300	300–400	400–500	500–750	
Peter the Great Bay	1691	5082	872	216	161	167	207	8396
Primorye, south of Cape Zolotoy	2644	6470	9112	3887	1518	1423	2568	27622
Primorye, north of Cape Zolotoy	5519	13664	8434	2519	1548	601	2654	34939
Western Sakhalin subzone	4146	8563	9393	3406	772	548	1750	28578
Total	14001	33779	27811	10027	3999	2739	7179	99535

tribution, and biomass of benthic macrofauna on the shelf and the continental slope of the northwestern Pacific (including the Sea of Japan), based on the mean long-term data of 1977–2010, have been published within the last 2 or 3 years [37, 38].

In 2015, a complex bottom trawl survey of the entire Russian sector of the Sea of Japan was performed. The results of the study of fish collected during this survey have already been discussed in the dedicated scientific literature [14, 15], while the data on invertebrates, except for a note on the biological status and distribution of the northern shrimp *Pandalus borealis* and the humpback shrimp *P. hypsinotus* [1], have not yet been published. The present article briefly describes the taxonomic composition, quantitative distribution, and biocenotic groups of trawl macrozoobenthos in the northern Sea of Japan, as inferred from the results of this survey.

MATERIALS AND METHODS

The bottom trawl survey in 2015 started in April from the western part of Peter the Great Bay and was completed in July in the waters off Cape Crillon, the western coast of Sakhalin Island (Fig. 1). The works were carried out aboard the R/V *Bukhoro* (a small shrimp-fish freezer trawler); trawl hauls were performed during daylight hours (from four to nine per each transect) using a 27.1/24.4-m bottom trawl of the DT/TV type with a mesh size of 30 mm in the cod end. To catch small animals, a fine-meshed (10 mm) liner was used in the trawl bag. The footrope was equipped with a soft chain groundrope with a length of 26.6 m. The length of the snood lines connecting the groundrope with the footrope at 1-m intervals was 20 cm. The SQM spherical otter boards had an area of 3.63 m^2. The trawling speed varied from 2.7 to 3.0 kt depending on depth, with an average of 2.8 kt. The planned duration of a trawl haul was 30 min, but on a rough (snaggy) bottom the duration was regulated depending on the trawling conditions. A total of 430 trawl hauls were performed in the depth range of 10–750 m.

Trawl catches of lower than 300 kg were completely sorted out to species, measured, and weighed. A larger catch was divided into parts, one of which was also sorted out, measured, and weighed; the resulting values were then expressed per total catch. The rest of the catch was examined for the presence of rare (for this catch) species. The biomass of invertebrates was calculated by the Thiessen polygon method (Voronoi diagram) in the ArcView v. 3.2a GIS software. To assess the effect of depth on the distribution of invertebrate animals, polygons of stations were built within the following depth ranges: less than 50, 100–150, 150–200, 200–300, 300–400, 400–500, and more than 500 m. For stations located in a selected depth range, polygons were built within this range. At the final stage, the area was calculated for all the polygons obtained this way. The values of the surveyed areas in different bathymetric ranges of certain parts of the northern Sea of Japan are shown in Table 1. Data were averaged over four areas, three of which were allocated in the Primorye subzone (Fig. 1): Peter the Great Bay with the adjacent continental slope (PGB); Southern Primorye (SP), between the capes Povorotny and Zolotoy; the northern part of the Primorye subzone (NP), north of Cape Zolotoy; and the Western Sakhalin subzone (WS). The horizontal opening of the bottom trawl was assumed to be equal to 60% of the length of its headrope [31]. To determine the biomass of invertebrates, values of catchability coefficients (CC) from 0.10 to 0.75 were used [21].

The biocenotic zoning of the northern Sea of Japan, or "... subdivision of the studied body of water into uniform areas in such a way that each of them would include a compact group with a more or less similar species structure" [34, p. 168], was carried out based on the obtained data on the quantitative composition of trawl macrozoobenthos in this region. In the case of such a "Petersen" approach, a group means a set of benthic animal species that inhabit a particular biotope and are characterized by certain quantitative proportions [27, 29][2]. We will refer to these groups as

[2] For more details on the conceptual specifics of this approach to biocenotic zoning, see the book of V.V. Sukhanov and O.A. Ivanov [34, Chapter 5].

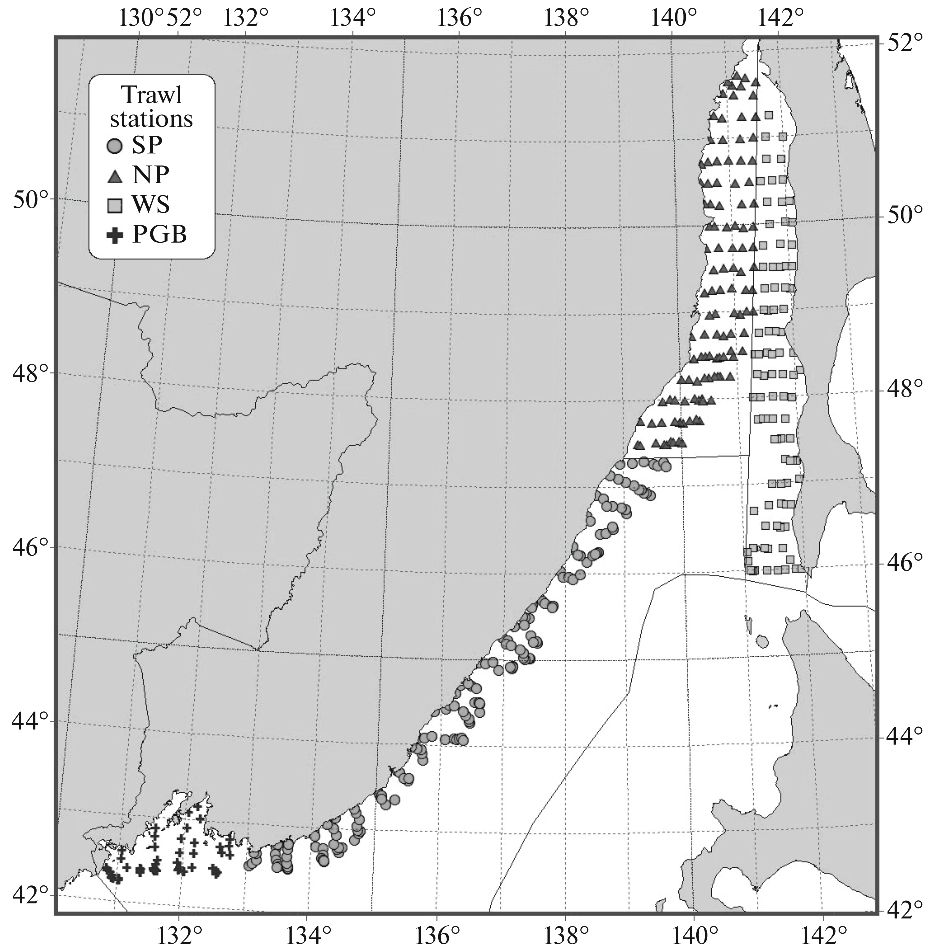

Fig. 1. Stations of bottom trawl surveys conducted aboard R/V *Bukhoro* in the Russian waters of the Sea of Japan (April 1–July 8, 2015). Biostatistical areas are as follows: PGB, Peter the Great Bay; SP, Southern Primorye; NP, Northern Primorye; WS, Western Sakhalin subzone.

"biocenotic complexes" [13]. They were identified by the species that is dominant in biomass [8, 20, 26, et al.]. All the stations at which the same one species, accompanied by a small number of characteristic species, dominated in biomass, were attributed to a certain biocenotic complex. Stations at which the leading species was not dominant or was absent, but the composition of the accompanying characteristic species and the biotope typical for this complex remained unchanged, were considered as belonging to the same complex.

RESULTS AND DISCUSSION

General Characteristics

A total of 211 taxa of invertebrates were recorded from trawl catches in the northern Sea of Japan (Table 2). The most widely represented of these were starfish (36), shrimp (32), gastropods (27), bivalves (23), brachyuran and anomuran crabs (11), polychaetes (11), coral polyps (10), and sponges (10). The remaining groups consisted of one to eight taxa.

One of the noteworthy finds was the catch of a male humpy shrimp *Pandalus goniurus* (with a body length of 57 mm) in the central part of Peter the Great Bay (42°46′ N, 131°58′ E) at a depth of 65 m. Previously, there were no reliable records of this species from the bay. In 1997–2014, humpy shrimp did not occur during bottom trawl surveys in the Primorye waters south of 45° N. In recent years, the abundance of this species has been observed to increase; since 2014, specialized fishing for this shrimp has been organized in the Tatar Strait (its main aggregations are located north of 48° N) [40]. Thus, the southward expansion of the *P. goniurus* distribution range can be related to the increase in its abundance.

The total recorded biomass of the macrozoobenthos in benthic biotopes of the northern Sea of Japan, 1572500 t, was distributed over the considered areas as follows: Peter the Great Bay, 136600 t (8.7%); Southern Primorye, 341500 (21.7%); Northern Primorye,

Table 2. The taxonomic composition and biomass (10^3 t) of the trawl macrozoobenthos in the biostatistical areas of the northern Sea of Japan in the spring and summer of 2015 (values in parentheses are the number of taxa per group)

Taxon	PGB	SP	NP	WS	Total
Porifera	38.359 (2)	10.067 (3)	117.263 (5)	17.231 (10)	182.920 (10)
Anthozoa	1.924 (5)	2.224 (6)	19.123 (7)	4.321 (9)	27.592 (10)
Nemertea	–	–	1.688 (2)	–	1.688 (2)
Polychaeta	0.020 (2)	0.098 (2)	4.812 (10)	2.075 (9)	7.005 (11)
Echiura	0.370 (1)	1.480 (1)	0.146 (1)	2.164 (2)	4.160 (3)
Sipunculidea	–	0.015 (1)	13.633 (1)	0.035 (1)	13.683 (1)
Cirripedia	0.006 (1)	0.011 (1)	0.455 (1)	0.535 (2)	1.007 (2)
Isopoda	–	–	0.014 (1)	0.076 (1)	0.090 (1)
Anomura	13.164 (2)	19.197 (5)	10.827 (4)	5.470 (4)	48.658 (5)
Brachyura	31.653 (4)	36.647 (4)	138.675 (6)	24.623 (5)	231.598 (6)
Caridea	7.315 (24)	49.630 (29)	92.418 (30)	77.534 (24)	226.897 (32)
Paguridae	1.511 (3)	1.707 (4)	11.727 (5)	4.455 (7)	19.400 (8)
Polyplacophora	–	1.018 (1)	0.092 (1)	0.005 (1)	1.115 (1)
Gastropoda	4.502 (20)	3.201 (18)	6.316 (19)	8.108 (22)	22.127 (27)
Bivalvia	5.756 (13)	11.643 (13)	9.474 (13)	22.663 (13)	49.536 (23)
Octopoda	0.143 (1)	0.443 (3)	0.748 (2)	0.604 (2)	1.938 (3)
Bryozoa	–	–	5.284 (1)	0.012 (1)	5.296 (1)
Brachiopoda	0.001 (1)	1.297 (1)	2.257 (1)	0.189 (1)	3.744 (1)
Asteroidea	8.329 (18)	8.452 (23)	35.108 (21)	25.294 (23)	77.183 (36)
Ophiuroidea	3.146 (4)	28.704 (3)	176.317 (6)	164.043 (4)	372.210 (7)
Echinoidea	1.680 (2)	29.372 (3)	15.143 (3)	12.835 (4)	59.030 (4)
Holothuroidea	11.475 (5)	12.930 (4)	10.253 (7)	3.209 (5)	37.867 (8)
Crinoidea	3.826 (1)	122.299 (1)	12.118 (1)	29.207 (1)	167.450 (1)
Ascidiacea	3.408 (6)	1.093 (5)	2.103 (6)	3.703 (4)	10.307 (8)
Total	136.588 (115)	341.528 (131)	685.994 (154)	408.391 (155)	1572.501 (211)
Number of trawl hauls	54	170	113	93	430

686000 t (43.6%); Western Sakhalin subzone, 408400 t (26.0%) (Table 2). The estimate obtained is substantially higher than the mean long-term value for the Sea of Japan, 634000 t [37]. This can be explained, in our opinion, by both objective and subjective factors. On the one hand, the current abundance of crabs and shrimps is evidently at an elevated level [16, 18, 32]. On the other hand, in many trawl surveys, the "hydrobiological" part of the catch was sorted out often quite superficially due to a lack of specialists, which resulted in an underestimation of benthic invertebrates [21].

The mean specific biomass of the trawl macrozoobenthos was 13.5 ± 1.1 g/m^2 (commercial benthos, 6.3 ± 0.5 g/m^2); this parameter varied between the areas as follows: Peter the Great, 16.5 ± 3.8 g/m^2 (8.5 ± 1.1 g/m^2); Southern Primorye, 10.4 ± 1.1 g/m^2 (5.9 ± 0.6 g/m^2); Northern Primorye, 16. 6 ± 2.6 g/m^2 (7.2 ± 1.2 g/m^2); Western Sakhalin subzone, 13.4 ± 2.1 g/m^2 (4.7 ± 1.5 g/m^2) (Table 3). The specific biomass of the benthos was naturally higher in the areas with a wide shelf (Peter the Great Bay and the Tatar Strait). For comparison, the mean biomass of the trawl benthos in Peter the Great Bay was 7.1 g/m^2 according to the data for 2006–2010 [5]; in the Tatar Strait it was 1.2 g/m^2 in 2007 [28].

The vertical distribution of both the total benthos and its commercially harvested species was characterized by maxima in the upper part of the shelf (10–50 m) and

Table 3. The bathymetric distribution of total biomass of trawl macrozoobenthos (I) and biomass of its commercial species (II) over the biostatistical areas in the spring and summer of 2015, g/m^2

Depth range, m	PGB		SP		NP		WS		Total	
	I	II	I	II	I	II	I	II	I	II
10–50	20.0 ± 4.1	14.0 ± 3.5	11.8 ± 2.9	9.3 ± 2.9	31.9 ± 11.0	3.1 ± 0.6	19.9 ± 12.3	15.7 ± 12.5	20.6 ± 4.2	8.8 ± 2.2
50–100	23.3 ± 14.1	6.3 ± 1.1	8.15 ± 1.0	6.4 ± 0.9	16.7 ± 3.7	13.2 ± 3.7	7.1 ± 1.3	3.7 ± 0.5	12.6 ± 2.2	7.9 ± 1.3
100–200	9.9 ± 1.9	6.9 ± 1.8	7.1 ± 1.9	3.9 ± 0.8	8.2 ± 0.8	3.9 ± 0.5	14.4 ± 3.4	4.0 ± 1.8	10.2 ± 1.4	4.2 ± 0.7
200–300	23.3 ± 7.9	12.1 ± 4.7	13.7 ± 4.4	4.5 ± 0.8	15.6 ± 2.8	9.6 ± 1.7	17.5 ± 7.5	2.8 ± 0.8	15.8 ± 2.6	6.2 ± 0.8
300–400	16.5 ± 4.9	14.4 ± 4.8	19.9 ± 5.2	8.1 ± 0.9	15.9 ± 5.3	7.0 ± 1.2	13.7 ± 6.0	2.1 ± 0.6	17.7 ± 3.1	7.8 ± 1.0
400–500	8.7 ± 3.1	5.1 ± 1.7	12.1 ± 1.3	7.2 ± 0.9	7.6 ± 2.0	3.6 ± 0.8	22.4 ± 16.5	1.9 ± 0.1	11.7 ± 1.5	5.9 ± 0.7
500–750	6.3 ± 2.0	2.3 ± 0.5	4.3 ± 0.6	2.4 ± 0.3	4.4 ± 1.0	1.6 ± 0.3	15.6 ± 9.3	0.6 ± 0.2	5.9 ± 1.2	2.1 ± 0.2
10–750	16.5 ± 3.8	8.5 ± 1.1	10.4 ± 1.1	5.9 ± 0.6	16.6 ± 2.6	7.2 ± 1.2	13.4 ± 2.1	4.7 ± 1.5	13.5 ± 1.1	6.3 ± 0.5

within the 300–400 m depth range; the minima were recorded from depths of 100–200 and 500–750 m (Table 3; Fig. 2). According to the mean long-term data, the maximum biomass of the trawl benthos was observed in the 500–1000 m depth range [38]. This discrepancy results from the fact that, in contrast to our work (see Table 2), V.P. Shuntov and I.V. Volvenko [38] attributed squids (including the magister armhook squid *Berrytheutis magister*), which are quite abundant at depths greater than 500 m, to the trawl benthos. As well, this discrepancy can be related to the difference in the range of the surveyed depths, as in the Sea of Japan the deep-sea red snow crab *Chionoecetes japonicus* forms significant aggregations at depths greater than 750 m [33].

In Table 4, data on the stocks of 50 commercial taxa of trawl macrozoobenthos and their distribution over the studied areas are provided. Their total recorded biomass amounted to 630000 t.

The following species showed the highest biomass values: snow crab *Chionoecetes opilio* (211400 t); two anomuran species of the genus *Paralithodes*, the red king crab *P. camtschaticus* (32700 t) and the blue king crab *P. platypus* (15700 t); horsehair crab *Erimacrus isenbeckii* (12800 t); humpy shrimp *P. goniurus* (100800 t), northern shrimp *P. borealis* (69300 t), and humpback shrimp *P. hypsinotus* (36700 t); sculptured shrimp *Sclerocrangon salebrosa* (4000 t); pale yellow sea urchin *Strongylocentrotus pallidus* (58000 t); sea peach *Halocynthia aurantium* (8500 t); Japanese cucumaria *Cucumaria japonica* (36200 t); white-pink

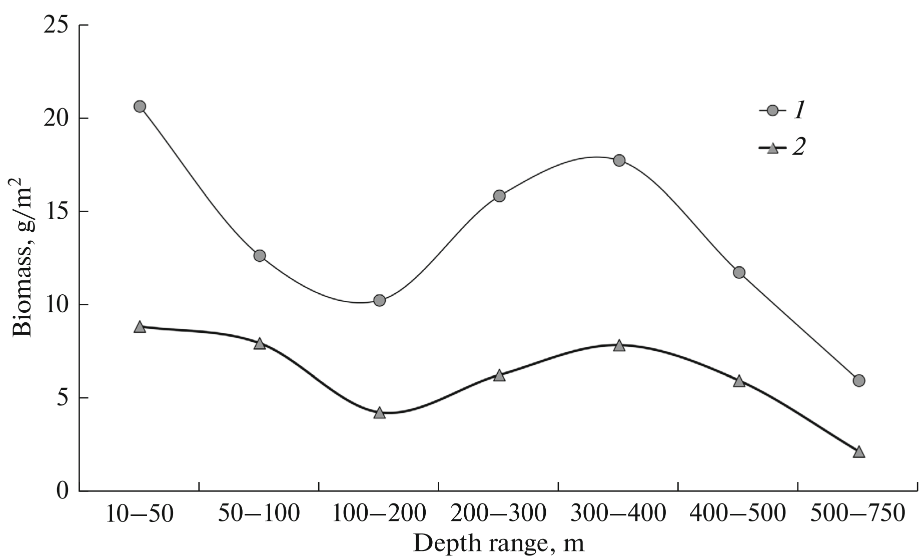

Fig. 2. Variations in mean biomass of the total trawl macrozoobenthos (*1*) and biomass of its commercial part (*2*) in the northern Sea of Japan depending on depth (based on the data of bottom trawl surveys in 2015).

Table 4. The biomass (10^3 t) of main commercial species of macrozoobenthos and its distribution over the biostatistical areas (%) of the northern Sea of Japan in the spring and summer of 2015

Taxon	CC	PGB		SP		NP		WS		Total
		10^3 t	%	10^3 t	%	10^3 t	%	10^3 t	%	10^3 t
Halocynthia aurantium	0.70	3.069	36.1	1.046	12.3	0.783	9.2	3.598	42.4	8.496
Paralithodes brevipes	0.75	–	–	0.271	95.0	0.007	2.5	0.007	2.5	0.285
P. camtschaticus	0.75	13.147	40.2	8.555	26.2	5.997	18.3	4.986	15.3	32.685
P. platypus	0.75	0.017	0.1	10.371	66.1	4.821	30.7	0.474	3.1	15.683
Chionoecetes japonicus	0.40	0.365	14.9	0.942	38.5	1.141	46.6	–	–	2.448
C. opilio	0.40	30.349	14.4	28.950	13.7	132.126	62.5	20.003	9.4	211.428
C. sp.*	0.40	0.011	9.9	0.104	90.1	–	–	–	–	0.115
Erimacrus isenbeckii	0.50	0.925	7.3	6.671	52.3	0.924	7.2	4.238	33.2	12.758
Telmessus cheiragonus	0.50	–	–	–	–	0.243	51.0	0.233	49.0	0.476
Lebbeus groenlandicus	0.25	0.014	1.9	0.224	30.6	0.468	63.9	0.027	3.6	0.733
Pandalopsis japonica	0.20	0.042	2.7	0.773	48.9	0.486	30.7	0.280	17.7	1.581
P. lamelligera	0.20	–	–	–	–	0.195	97.1	0.006	2.9	0.201
Pandalus borealis	0.25	2.339	3.4	33.686	48.6	24.440	35.2	8.883	12.8	69.348
P. goniurus	0.20	0.001	+	0.049	+	43.875	43.5	56.845	56.5	100.770
P. hypsinotus	0.20	3.922	10.7	12.978	35.4	12.691	34.6	7.078	19.3	36.668
Sclerocrangon boreas	0.30	0.002	0.2	0.198	19.7	0.346	34.3	0.461	45.8	1.007
S. salebrosa	0.30	0.597	15.0	0.005	0.1	2.158	54.1	1.227	30.8	3.987
Echinarachnius parma	0.50	–	–	0.048	27.6	0.086	49.2	0.041	23.2	0.175
Strongylocentrotus pallidus	0.70	1.668	2.9	28.671	49.4	14.853	25.6	12.789	22.1	57.981
S. intermedius	0.70	0.012	1.4	0.653	74.7	0.204	23.4	0.005	0.5	0.874
Apostichopus japonicus	0.70	0.004	100.0	–	–	–	–	–	–	0.004
Cucumaria glacialis	0.70	–	–	–	–	0.001	100.0	–	–	0.001
C. japonica	0.70	11.359	31.4	12.797	35.3	9.934	27.4	2.138	5.9	36.228
Chlamys chosenica	0.50	0.003	0.1	5.929	99.7	0.013	0.2	–	–	5.945
C. cf. *albida*	0.50	–	–	–	–	–	–	0.097	100.0	0.097
Swiftopecten swiftii	0.70	0.001	1.3	0.051	50.1	0.049	48.6	–	–	0.101
Crassostrea gigas	0.50	–	–	–	–	0.009	92.6	0.001	7.4	0.010
Crenomytilus grayanus	0.50	0.236	5.2	2.369	52.1	1.942	42.7	–	–	4.547
Mizuhopecten yessoensis	0.50	0.066	2.1	2.571	82.5	0.469	15.1	0.011	0.3	3.117
Serripes groenlandicus	0.20	0.042	42.2	0.032	32.1	0.026	25.7	–	–	0.100
Spisula sachalinensis	0.05	–	–	–	–	–	–	0.198	100.0	0.198
Octopus conispadiceus	0.50	0.081	11.3	0.180	25.1	0.280	39.1	0.175	24.5	0.716
O. cf. *yendoi*	0.50	0.024	27.5	0.064	72.4	–	–	+	0.1	0.088
O. sp.	0.50	0.038	19.5	0.086	43.9	0.072	36.6	+	+	0.196
Enteroctopus dofleini	0.50	–	–	0.100	10.8	0.396	42.8	0.429	46.4	0.925
Ancistrolepis decorus	0.50	–	–	–	–	0.206	61.6	0.129	38.4	0.335
Buccinidae fam. gen. spp.	0.50	0.001	4.7	–	–	0.015	91.8	0.001	3.5	0.017
Buccinum bayani	0.50	0.208	8.8	0.374	15.8	0.771	32.5	1.019	42.9	2.372
B. ochotense	0.50	–	–	+	100.0	–	–	–	–	+
B. rossicum	0.50	+	+	0.029	5.9	0.190	37.7	0.283	56.4	0.502
B. sp.	0.50	–	–	0.017	24.0	0.053	76.0	–	–	0.070
B. verkruzeni	0.50	0.227	14.4	0.014	0.9	0.064	4.0	1.271	80.7	1.576
Lussivolutopsius emphaticus	0.50	0.015	10.3	0.058	39.2	0.056	38.1	0.018	12.4	0.147

Table 4. (Contd.)

Taxon	CC	PGB		SP		NP		WS		Total
		10^3 t	%	10^3 t	%	10^3 t	%	10^3 t	%	10^3 t
Neptunea bulbacea	0.50	0.167	44.8	0.087	23.3	0.108	29.0	0.011	2.9	0.373
N. constricta	0.50	2.818	38.3	0.818	11.1	1.127	15.3	2.594	35.3	7.357
N. intersculpta	0.50	0.169	4.0	0.987	23.3	2.110	49.8	0.973	22.9	4.239
N. lyrata	0.50	0.182	8.9	0.213	10.4	1.153	56.5	0.491	24.2	2.039
N. polycostata	0.50	0.414	42.1	0.149	15.1	0.257	26.2	0.163	16.6	0.983
Volutopsius castaneus	0.50	–	–	–	–	0.005	100.0	–	–	0.005
Total	–	72.535	11.5	161.116	25.6	265.150	42.1	131.185	20.8	629.986

CC, catchability coefficient [21]; "+", biomass is lower than 1 t and proportion is smaller than 0.1%. * Hybrid of *Chionoecetes japonicus* and *C. opilio*.

scallop *Chlamys chosenica* (6000 t); Gray's mussel *Crenomytilus grayanus* (4500 t); Yesso scallop *Mizuhopecten yessoensis* (3100 t); four octopod species (2700 t); and 14 species and forms of gastropods of the family Buccinidae (20000 t). A major portion of the commercially harvested benthos (265200, or 42.1%) was concentrated in the waters adjacent to the mainland coast of the Tatar Strait (Primorye subzone north of Cape Zolotoy) (Table 4).

The integral maps of the distribution of the total trawl benthos, its harvested part, as well as some commercially important taxonomic groups, are shown in Figs. 3–7. In general, it can be noted that among the most common taxonomic groups starfishes and holothurians were most abundant within the depth range of 10–50 m; sponges and sea urchins, within 10–200 m; pagurid crabs, within 10–100 m; gastropods, within 50–100 m; and anomuran crabs, within 10–300 m (Table 5).

Crabs were quite abundant in the entire surveyed depth range; their largest aggregations were confined to depths of 50–300 m (Table 5). The biomass of shrimps was at a maximum at depths of 200–500 m; bivalve mollusks, 10–100 and 200–400 m; brittle

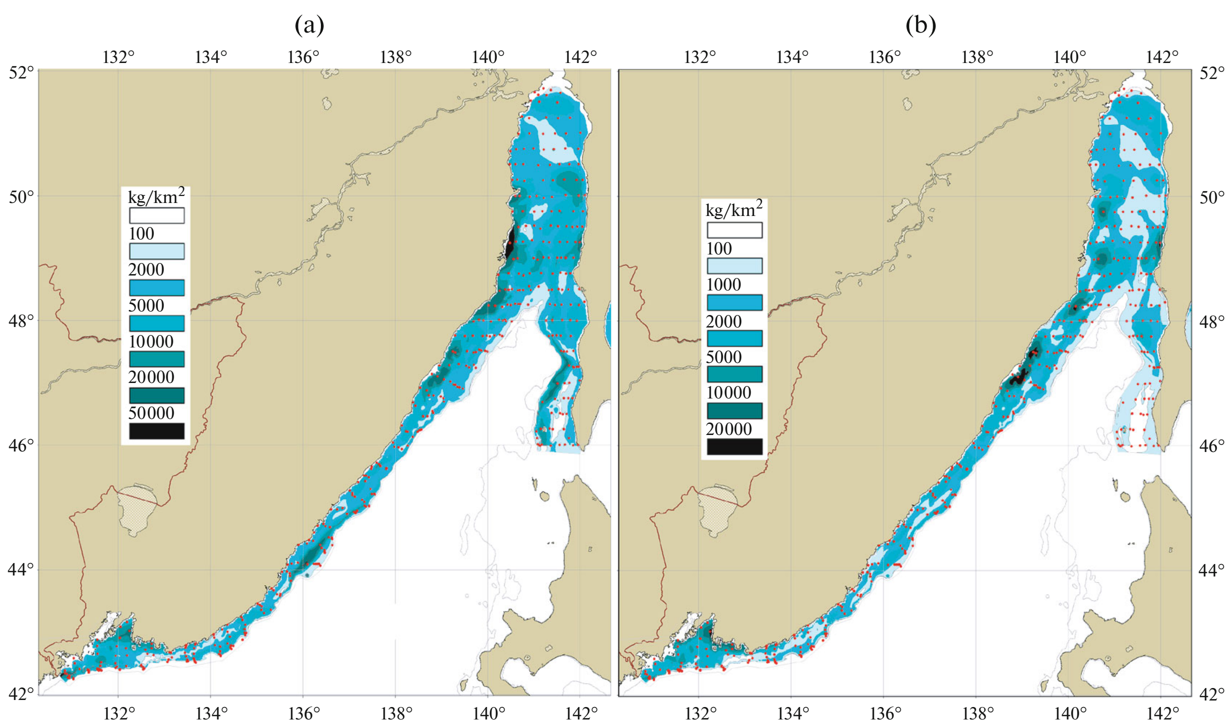

Fig. 3. The distribution of trawl macrozoobenthos (kg/km^2) in the northern Sea on Japan (April 1–July 8, 2015): (a) total biomass; (b) biomass of commercial species.

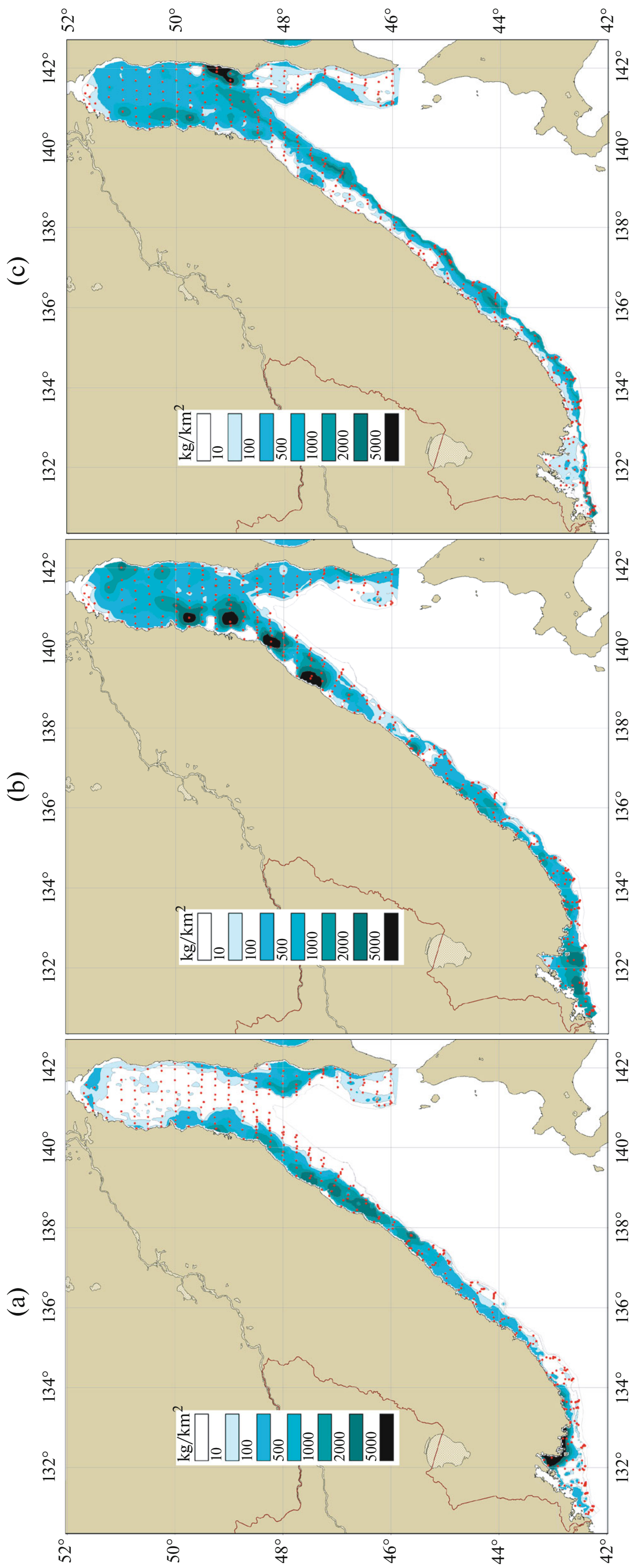

Fig. 4. The distribution of Anomura (a), Brachyura (b), and Caridea (c) in the northern Sea of Japan (April 1–July 8, 2015), kg/km^2.

stars, 10–50 and 100–500 m. The maxima of abundance of coral polyps were recorded from depths of 10–50, 100–300, and 500–750 m; the sea lily *Heliometra glacialis* proved to be the deepest-dwelling species (100–750 m) (Table 5).

Biocenotic Complexes

A total of 18 complexes were identified in the trawl macrozoobenthos in the northwestern Sea of Japan, of which 7 were dominated by crustaceans; 3, by bivalve mollusks; and the remaining 8 complexes were dominated by members of various taxonomic groups (Fig. 8, Table 6). The group of the sea lily (with its biomass of 5.5 g/m^2, depth range of 104–692 m, and 131 stations), which is a sedentary seston-feeder, occupied the largest area of the bottom; somewhat smaller areas were occupied by the group of the polyphagous snow crab (4.4 g/m^2, 27–552 m, and 71 stations), the group of the mobile seston-feeding basket star *Gorgonocephalus eucnemis* (6.6 g/m^2, 58–372 m, and 40 stations), and the polyphagous pale yellow sea urchin (4.7 g/m^2, 17–351 m, and 40 stations). The highest biomass and largest proportion of dominance were recorded for the complex of sponges (31.0 g/m^2, 81.7%); the lowest biomass was found for the group of northern shrimp *P. borealis*, 1.5 g/m^2; the smallest proportion of dominant species was found for the complex of Gray's mussel *C. grayanus*, 34.0%.

CONCLUSIONS

In the spring–summer period of 2015, a total of 211 invertebrate taxa were recorded from trawl catches on the shelf and continental slope (10–750 m) in Russian waters of the Sea of Japan. The most widely represented of them were starfishes (36), shrimps (32), gastropods (27) and bivalve mollusks (23), brachyuran and anomuran crabs (11), polychaetes (11), coral polyps (10), and sponges (10).

The total recorded biomass of macrozoobenthos in benthic biotopes of the northern Sea of Japan amounted to 1572500 t (Peter the Great Bay, 136600 t; Southern Primorye, 341500t; Northern Primorye, 686000 t; Western Sakhalin subzone, 408400 t).

The stock of commercial invertebrates constituted 630000 t, a major part of which (265200 t, or 42.1%) was concentrated in the Primorye subzone north of Cape Zolotoy (the waters adjacent to the mainland coast of the Tatar Strait). Approximately half of the total commercial stock was formed by only two species, the snow crab (211400 t) and humpy shrimp (100800 t).

The mean specific biomass of the trawl macrozoobenthos was 13.5 ± 1.1 g/m^2 (including commercially harvested benthos, 6.3 ± 0.5 g/m^2). The most abundant groups were brittle stars (372200 t), brachyuran (231600 t) and anomuran crabs (48700 t), shrimps

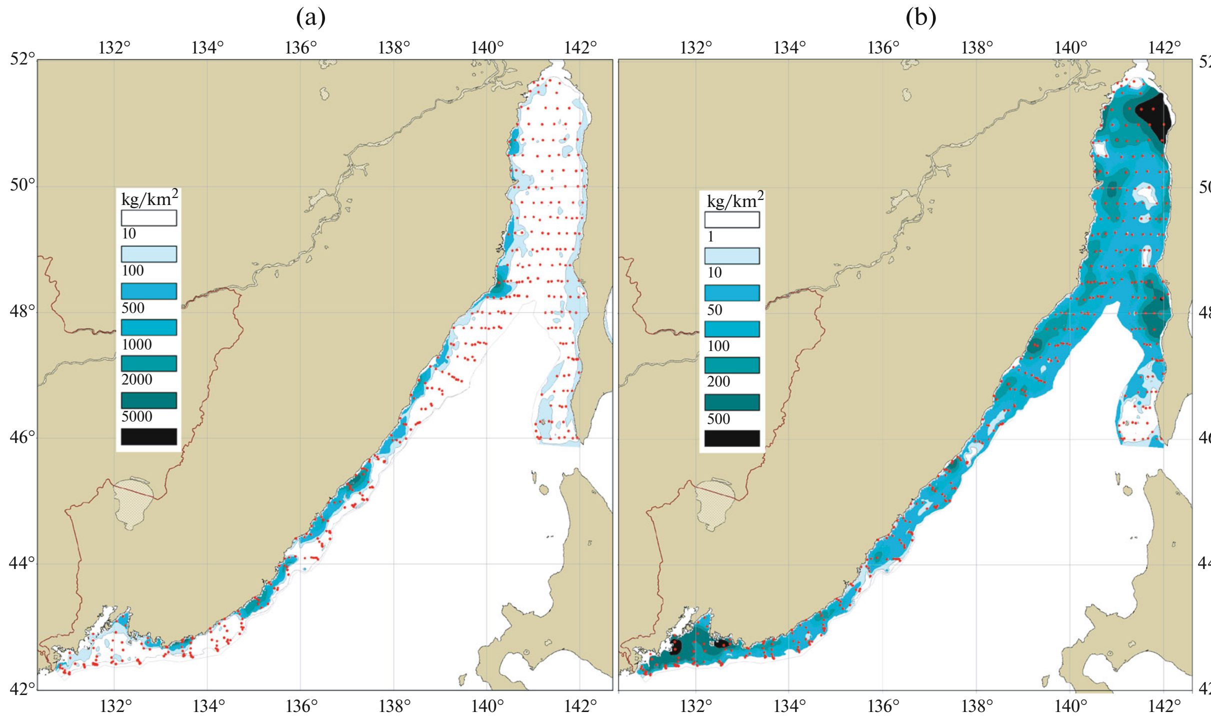

Fig. 5. The distribution of Bivalvia (a) and Gastropoda (b) in the northern Sea of Japan (April 1–July 8, 2015), kg/km^2.

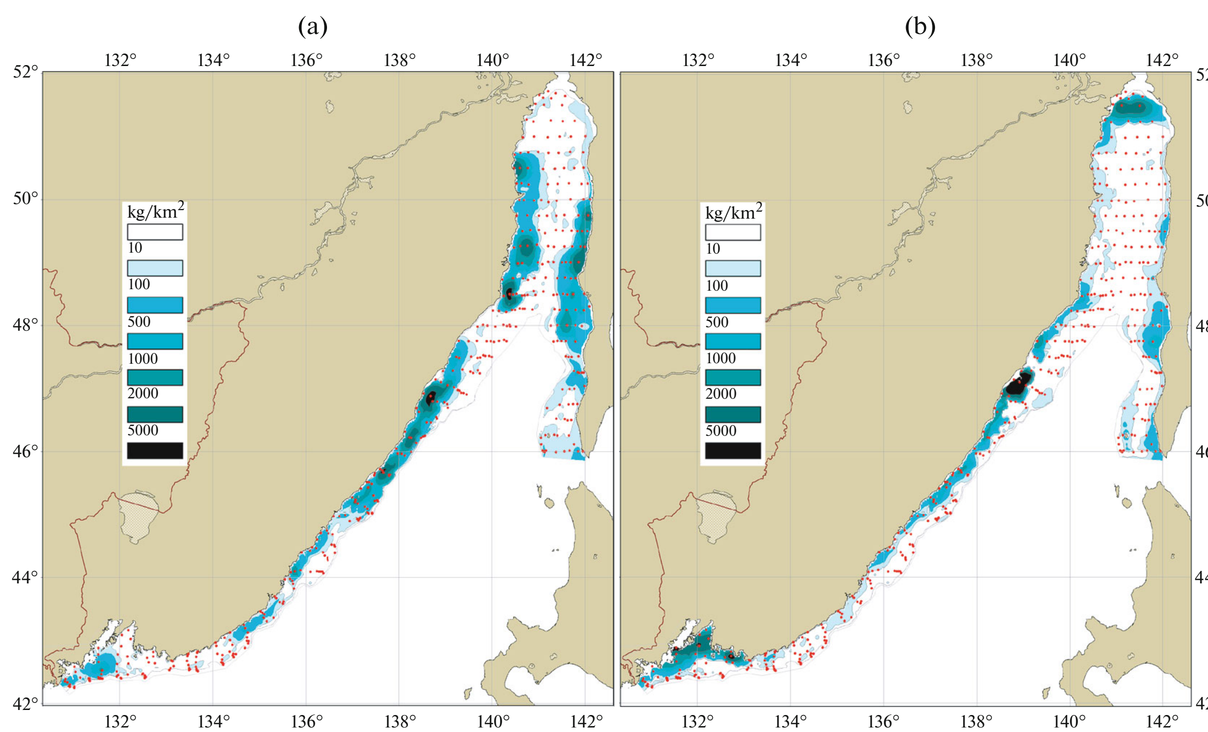

Fig. 6. The distribution of Echinoidea (a) and Holothuroidea (b) in the northern Sea of Japan (April 1–July 8, 2015), kg/km^2.

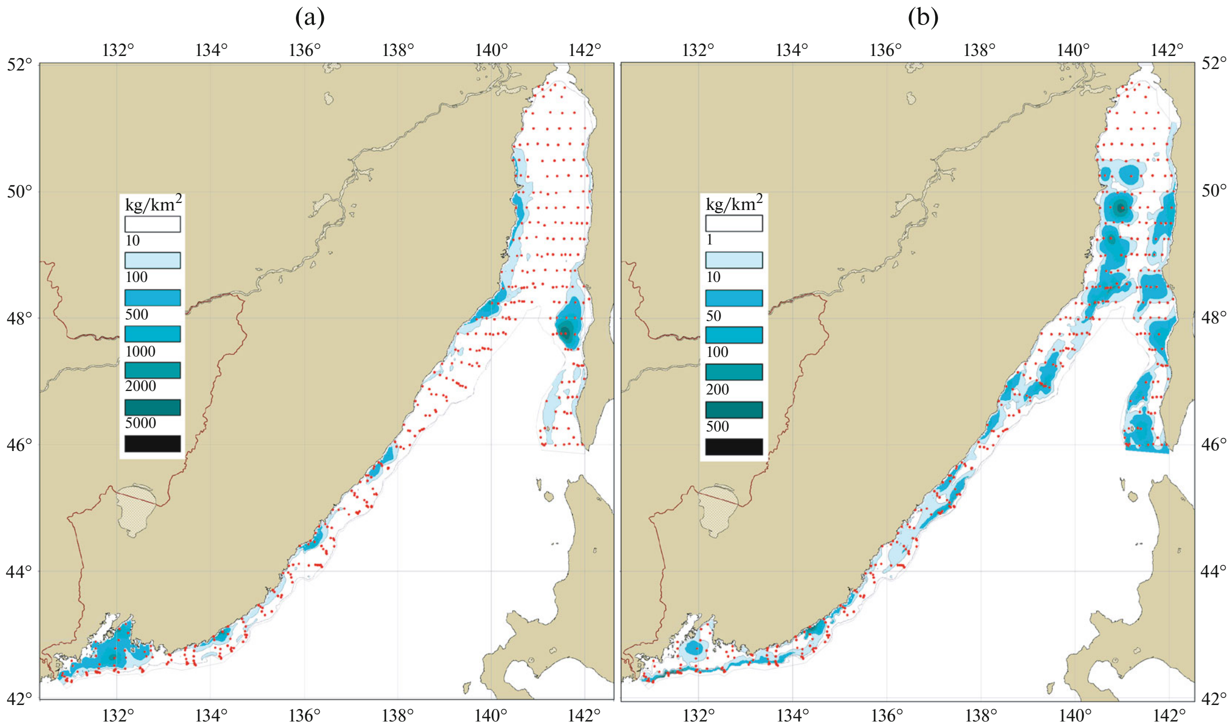

Fig. 7. The distribution of Ascidiacea (a) and Octopoda (b) in the northern Sea of Japan (April 1–July 8, 2015), kg/km^2.

(226900 t), sponges (182900 t), sea lilies (167500 t), starfishes (77200 t), sea urchins (59000 t), and bivalves (49500 t).

The vertical distribution of both the total benthos and its commercial species was characterized by maxima in the upper part of the shelf (10–50 m) and within the depth range of 300–400 m.

A total of 18 biocenotic complexes were identified in the composition of trawl macrozoobenthos in the northwestern Sea of Japan. The largest areas were occupied by the group of sedentary seston-feeding sea lily (biomass 5.5 g/m^2, depth range 104–692 m, and 131 stations), the group of the polyphagous snow crab (4.4 g/m^2, 27–552 m, and 71 stations), the group of the mobile seston-feeding basket star (6.6 g/m^2, 58–372 m, and 40 stations), and the group of the polyphagous pale yellow sea urchin (4.7 g/m^2, 17–351 m, and 40 stations).

Table 5. The vertical distribution of the most common taxonomic groups of trawl macrozoobenthos in the northern Sea of Japan in the spring and summer of 2015, kg/km^2

Depth range, m	Porifera	Anthozoa	Anomura	Brachyura	Caridea	Paguridae	Gastropoda	Bivalvia	Asteroidea	Ophiuroidea	Echinoidea	Holothuroidea	Crinoidea
10–50	1943.2	204.3	1488.0	726.3	313.8	167.3	68.4	784.3	819.7	2637.2	234.7	2245.3	0.0
50–100	1987.5	52.3	411.3	2647.3	227.2	291.0	107.0	574.6	138.6	727.6	1135.6	196.5	14.0
100–200	569.8	358.4	184.5	1308.4	541.0	94.1	45.9	59.1	28.8	2788.1	354.1	13.1	1151.0
200–300	78.9	253.2	127.6	1522.9	770.2	19.4	71.3	428.3	43.8	1620.4	121.5	22.1	5442.4
300–400	15.6	25.9	2.0	591.4	1271.5	20.7	39.9	114.8	103.4	4754.9	131.8	105.2	4380.7
400–500	16.0	49.7	3.5	554.5	989.7	26.1	41.5	29.7	128.1	1877.4	112.8	233.5	2884.4
500–750	2.1	172.4	0.0	534.1	437.3	0.7	36.1	2.8	42.5	559.6	9.5	154.6	1575.7
10–750	953.1	179.1	404.3	1386.0	529.0	126.4	66.0	348.0	201.9	1990.4	432.6	463.7	1602.6

Cells with local maxima of abundance are filled with grey.

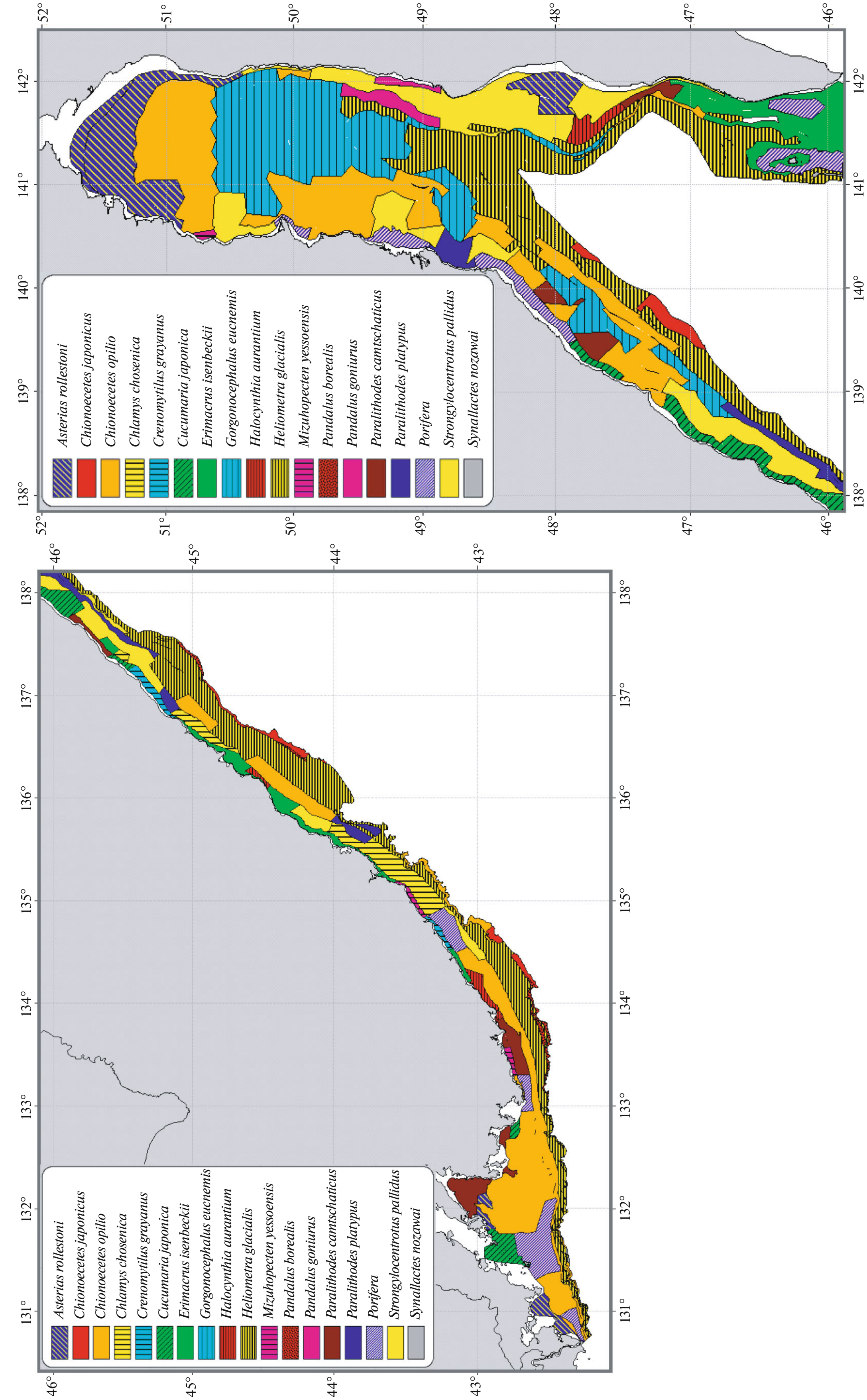

Fig. 8. Biocenotic complexes of trawl macrozoobenthos in the northern Sea of Japan (April–July 2015).

Table 6. The characteristics of the biocenotic complexes of trawl macrozoobenthos in the northern Sea of Japan in the spring and summer of 2015

Biocenotic complex	B_{tot}, kg/km^2	B_{ed}, kg/km^2 (portion, %)	Subdominants	Portion, %	Depth range, m	Number of stations	Trophic characteristics
Heliometra glacialis	5525.0 ± 682.7	3587.8 ± 636.9 (64.9)	*Pandalus borealis*	13.3	104–692	131	SS
			Chionoecetes opilio	4.6			
			Pandalus hypsinotus	3.9			
Chionoecetes opilio	4416.2 ± 758.2	2463.3 ± 615.4 (55.8)	Actiniaria	4.1	27–552	71	P
			Paralithodes camtschaticus	3.7			
			Pandalus hypsinotus	3.3			
			Pandalus goniurus	3.1			
			Pandalus borealis	2.5			
			Heliometra glacialis	2.6			
Gorgonocephalus eucnemis	6624.9 ± 896.9	4592.1 ± 831.9 (65.1)	*Chionoecetes opilio*	11.9	58–372	40	MS
			Halipteris finmarchica	8.2			
Erimacrus isenbeckii	1900.8 ± 479.1	830.6 ± 277.4 (43.7)	*Evasterias echinosoma*	19.3	20–220	25	P
			Cucumaria japonica	4.2			
			Paralithodes camtschaticus	5.1			
Strongylocentrotus pallidus	4742.8 ± 599.5	2589.1 ± 472.7 (54.6)	*Paralithodes platypus*	6.6	17–351	40	P
			Paralithodes camtschaticus	6.5			
			Cucumaria japonica	4.4			
Asterias rollestoni	5428.9 ± 1223.0	2903.2 ± 883.1 (53.5)	*Cucumaria japonica*	17.8	10–64	20	C
			Distolasterias nipon	4.4			
			Metridium senile	3.8			
Paralithodes platypus	1656.5 ± 507.4	864.3 ± 470.8 (52.2)	*Paralithodes camtschaticus*	13.2	42–233	9	P
			Strongylocentrotus pallidus	8.4			
			Pandalus hypsinotus	5.2			
Paralithodes camtschaticus	6917.7 ± 1890.4	4598.2 ± 1695.0 (66.5)	*Chionoecetes opilio*	7.0	23–119	15	P
			Cucumaria japonica	6.4			
			Halocynthia aurantium	2.8			

Table 6. (Contd.)

Biocenotic complex	B_{tot}, kg/km^2	B_{ed}, kg/km^2 (portion, %)	Subdominants	Portion, %	Depth range, m	Number of stations	Trophic characteristics
Cucumaria japonica	9305.4 ± 4107.6	6486.3 ± 3910.0 (69.7)	*Paralithodes camtschaticus*	6.8	18–64	13	MS
			Paralithodes platypus	3.9			
Porifera	31045.5 ± 11347.3	25364.7 ± 11091.0 (81.7)	Bryozoa	5.0	32–145	15	SS
Chionoecetes japonicus	1438.2 ± 503.3	773.8 ± 484.3 (53.8)	Actiniaria	14.6	550–750	13	P
			Pandalus borealis	13.6			
Chlamys chosenica	3559.7 ± 610.5	1337.8 ± 344.7 (37.6)	Porifera	18.0	54–126	10	SS
			Pteraster tesselatus	8.3			
			Paralithodes camtschaticus	6.2			
			Erimacrus isenbeckii	6.0			
			Strongylocentrotus pallidus	5.0			
Pandalus borealis	1533.9 ± 151.0	838.3 ± 133.9 (54.7)	*Chionoecetes japonicus*	9.4	340–728	8	P
			Chionoecetes opilio	8.1			
			Actiniaria	7.5			
			Pandalus hypsinotus	5.7			
Halocynthia aurantium	4034.3 ± 636.6	1922.2 ± 451.0 (47.7)	*Paralithodes camtschaticus*	23.6	40–77	6	SS
Mizuchopecten yessoensis	9445.8 ± 2853.2	6392.7 ± 2282.4 (60.8)	*Erimacrus isenbeckii*	12.5	23–34	4	MS
			Paralithodes camtschaticus	4.7			
Synallactes nozawai	2772.7 ± 863.8	1496.8 ± 330.7 (54.0)	Asteroidea	11.8	308–670	3	OD
			Pandalus hypsinotus	8.2			
Pandalus goniurus	16031.3 ± 6257.7	13778.3 ± 5396.6 (86.0)	*Strongylocentrotus pallidus*	8.6	39–107	3	P
Crenomytilus grayanus	4916.8 ± 661.5	1669.9 ± 722.3 (34.0)	*Pododesmus macrochisma*	23.7	19–39	3	SS
			Metridium senile	7.5			
			Evasterias echinosoma	7.8			

B_{tot}, kg/km^2, total biomass of biocenotic complex; B_{ed}, kg/km^2, biomass of dominant species; SS, sedentary seston-feeders; MS, mobile seston-feeders; OD, obligatory detritus-feeders; P, polyphagous; C, carnivorous.

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